BI-CROPPING OF WINTER WHEAT AND WHITE CLOVER

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SUMMARY

Growing cereals in a leguminous living mulch (bi-cropping) could potentially reduce the need for synthetic inputs to cereal production while preventing losses of nutrients and increasing soil biological activity. The objective of this project was to investigate how bi-cropping (a low input production system for cereals) would compare with conventional winter wheat production systems in terms of total biomass, grain yield and biological diversity.

The study, carried out between 1994 and 1997, comprised of replicated plot experiments where various factors such as nitrogen and fungicide use were examined in both a conventional system of production and in a bi-cropped system. In the latter, winter wheat (cv. Hereward) was direct drilled into a defoliated white clover (cv. Donna) sward and grown with various crop inputs. Following the wheat harvest clover was allowed to regrow before being defoliated and the plots redrilled with wheat.

Above ground wheat dry matter accumulation measured at regular intervals during the season were significantly ($P<0.01$) lower in the bi-cropped treatments in all three seasons. Grain yields were strongly related to input levels, however the bi-cropped system was significantly lower in yield compared to conventional production systems. This reduction in yield was due to low numbers of ears per m^2 and low numbers of grains per ear. Lack of nitrogen availability during the early stages of crop development prevented the formation of tillers and grain sites and consequently reduced the yield potential of the bi-cropped treatments.

Although grain yields were disappointing the beneficial effects of the bi-cropped system were evident. In general the conventional production system had significantly higher levels of aphid infection and slug damage compared to the bi-cropped system, while earthworms were more prevalent in the bi-cropped areas.

This study has resulted in valuable information on bi-cropping being generated as well as identifying the potential benefits that can be expected under Irish conditions. While the results indicate that winter wheat can be successfully established in an understorey of white clover if sown early in good conditions, competition from grass weed species represents a serious impediment to

successful bi-cropping in the longer term. Consequently further research is needed before such a system can be presented to the agricultural community.

INTRODUCTION

Growing cereals in a leguminous living mulch (bi-cropping) such as white clover which utilises biologically fixed nitrogen could potentially reduce the need for synthetic inputs in cereal production while preventing losses of nutrients and increase soil biological activity. This work was part of an EU sponsored research programme in three EU countries, the objective of which was to evaluate the use of bi-cropping in winter wheat production and to determine the implications for nitrogen use, production inputs and general bio-diversity compared with conventional crop production systems.

METHODS

The field investigations were carried out at Oak Park Research Centre, Carlow . The soil is a free draining medium-heavy textured limestone soil with 3% organic carbon content. White clover (cv. Donna) was sown on 28th April 1994. The clover was drilled at a seeding rate of 9.0 kg/ha in rows 15 cms apart. The clover was cut, wilted for three days and baled as silage during 1st to 3rd of September. Clover re-growth was grazed with sheep from the 3rd to 17th October. All areas of the field received a commercial fertiliser containing 0 N:10P:20K at 370 kg/ha on 10th October 1994. All areas of the field received 70 kg/ha K in March 1995 as soil analysis had indicated the level of this element to be particularly low.

There were four treatments in four blocks as follows:

(1) winter wheat drilled into a white clover sward, no fertiliser nitrogen, no plant protection chemicals;

(2) winter wheat drilled into a white clover sward, 50 kg N/ha, low input of plant protection chemicals:

(3) winter wheat sown into a conventional ploughed seedbed, 160 kg N/ha, low input of plant protection chemicals;

(4) winter wheat sown into a conventional (ploughed) seed bed, 200 kg N/ha, high input of plant protection chemicals.

Winter wheat (Hereward) was sown into the clover plots with a Hunter Rotaseeder drill at a seeding rate of 200 kg/ha, 22.8 cm row spacing and in the conventional plots at 200 kg/ha, 12 cm row spacing. Nitrogen as calcium ammonium nitrate was applied at 50 kg/ha for treatment (2) and at 70 kg/ha in treatments (3) and (4) in March. The remaining N was applied to treatments (3) and (4) when the plants were at g.s. 31-32. Treatment 1 received no fungicide, treatments 2 and 3 received two half-rate fungicide applications, treatment 4 received three full rate fungicide applications. Treatments 1 and 2 received one herbicide application in year three (Avidex granules to control grass weeds), treatment 3 received one half-rate herbicide application each Autumn while treatment 4 received a full rate herbicide application each Autumn. Treatment 4 received a full rate insecticide application each Autumn. Both treatments 3 and 4 received insecticide applications each July, treatments 1 and 2 only received one insecticide application in July 1996. Assessments were made of crop establishment, whole crop silage yield and quality, grain yield and quality, leaf damage caused by pests and disease as well as an assessment of aphid numbers and aphid transmitted virus disease.

The trial was harvested in August. Two 60 m swaths were harvested from each plot, the average of which characterised the plot yield. Straw from all plots was baled and removed. Clover was cut on 15th September and again on 17th October.

RESULTS AND DISCUSSION

Establishment, growth and tillering of wheat plants

In all three years of the study plant establishment was lower in the bi-cropped treatments in comparison to the conventional treatments. On all sampling dates with the exception of January and March 1996 conventional treatments had significantly ($p > 0.05$) more plants per m^2 compared to bi-cropped treatments. Additionally bi-cropped treatments had significantly fewer ($p > 0.05$) tillers per m^2 compared to conventional treatments.

No differences were evident between the two bi-cropped treatments with the exception of the last sampling date in 1995 when the high input bi-cropped treatment had significantly higher ($p > 0.05$) numbers of plants/m^2 compared to the low input treatment.

In the first growing season dry weight of wheat plants/m^2 was significantly ($p>0.05$) greater in the conventional treatments at the first sampling date in November, differences between treatments increased thereafter. In the second growing season the dry weight of wheat plants/m^2 did not differ significantly among treatments until March 1996. By May of that year conventional treatments had accumulated approximately double the dry weight of bi-cropped treatments. In the third growing season dry weight of wheat plants was significantly greater in the conventional treatments throughout the growing season.

Clover progress

The length and dry weight of clover stolons and the dry weight of clover roots was assessed on two occasions during each growing season. Clover progress did not differ significantly between the two bi-cropped treatments.

Whole crop silage

Silage dry matter yields from the conventional treatments were significantly ($p>0.05$) greater than yields from bi-cropped treatments while the high input bi-cropped treatment significantly ($p >0.05$) out-yielded the low input bi-cropped treatment (Table 2). Yields from all treatments declined during the course of the study. Small differences in silage quality parameters were observed between treatments. In 1996 the high input bi cropped treatment was found to have a significantly higher percentage of dry matter digestibility when compared to the low input conventional treatment. In 1995 silage from the high input bi-cropped treatment had significantly lower ($p>0.05$) percentage nitrogen when compared to both the low input bi-cropped treatment and the high input conventional treatment. In 1996, the percentage nitrogen in whole crop silage was higher in bi-cropped treatments, silage from the low input bi-cropped treatment had significantly ($p>0.05$) more nitrogen when compared to the low input conventional treatment. In 1997 digestibility was higher in silage from conventional treatments. Silage from the high input conventional treatment had significantly higher digestibility ($p>0.05$) compared to both bi-cropped treatments while silage from the low input conventional treatment had significantly higher digestibility compared to the low input bi-cropped treatment.

Bi-cropped treatments had significantly more weeds when compared to conventional treatments. Of the two bi-cropped systems, the high input system had significantly ($p>0.05$) more weeds when compared to the low input bi-cropped system. There was no significant difference in clover yields between the two bi-cropped systems.

Grain harvest

Grain yields were strongly related to input levels (Table 1), significantly ($p>0.05$) higher grain yields were obtained from conventional treatments. The high input bi-cropped treatment out-yielded the low input bi-cropped treatment in all three years of the study. In 1995 and 1996 this difference was significant ($p>0.05$). The high input conventional treatment yielded significantly ($p>0.05$) more grain when compared to the low input conventional system in all three years of the study. Yield differences were primarily attributable to differences in the number of ears/m^2 and in the number of grains/ear, individual grain weight was relatively stable between treatments. During the course of the study yields of conventional treatments declined whereas yields of bi-cropped treatments were relatively stable. Grain from the high input conventional treatment had the greatest values of percentage protein in all three years. In 1996 hectolitre weight and percentage screenings were significantly higher in conventional treatments compared to bi-cropped treatment.

Pests and diseases

Aphid sampling in April 1995 showed significantly ($p>0.05$) lower aphid numbers in the high input conventional treatment, the only treatment which had received an aphicide the previous Autumn. Aphid numbers were significantly higher in the ears of bi-cropped treatments compared to conventional treatments in June.

Aphid sampling in May 1996 showed that there were significantly more aphids in the low input conventional treatment compared to all other treatments. In June aphids were found on the leaves of conventional treatments but not on the leaves of the bi-cropped treatments, the low input conventional treatment had significantly ($p>0.05$) more aphids compared to both bi-cropped treatments. The number of ear attacking aphids did not differ significantly between treatments.

Aphid sampling in November 1996 showed that there were significantly ($p>0.05$) more aphids in the high input bi-cropped treatment compared to all other treatments. No aphids were found in any of the treatments in April 1997. The number of aphids on flag leaves and ears did not differ significantly between treatments in July 1997.

Visual inspection in the first two years of the experiment failed to reveal any symptoms of barley yellow dwarf virus. Similarly the ELISA test failed to show differences between treatments. In 1997 visual scoring and ELISA testing revealed only a small level of barley yellow dwarf virus infection. Both methods of assessment, however, indicated that the high input conventional treatment had a significantly ($p>0.05$) higher level of infection compared to all other treatments.

Assessments of clover damage caused by slugs, beetles (*Sitona* and *Apion*) and the fungus *Leptosphaerulina trifolii* indicated that there were no significant differences between bi-cropped treatments on any of the occasions on which assessments were made. In 1995 most damage was caused by fungal pathogens. However in March 1996 most damage was caused by beetles while in November 1996 and March 1997 most damage was caused by slugs.

Slug damage to cereal leaves was assessed twice during each growing season, in November and again in January. There were no significant differences between treatments in the 1994/95 growing season and only a small amount of slug damage was evident. Similarly only a small amount of slug damage was evident in the 1995/96 growing season although slug damage was greatest in conventional treatments. In January 1996 both conventional treatments had significantly ($p>0.05$) greater slug damage in comparison to both bi-cropped treatments. Considerable damage was found in all treatments in October 1997 although damage was greatest in conventional treatments. The high input conventional treatment had significantly more slug damage ($p >0.05$) compared to all other treatments on this occasion while the low input conventional treatment had significantly more slug damage when compared to the high input bi-cropped treatment. Slug damage was not as extensive when this parameter was assessed in January 1997 when there were no significant differences between treatments.

Cost analysis

A comparison of the costs involved in grain production from bi-cropped and conventional systems is presented in Tables 3, 4 and 5 for the 1994/95, 1995/96 and the 1996/97 growing seasons respectively. The analysis excludes fixed cost and land rental and assumes equal grain and straw prices in both years. Calculation of profit per hectare does not include EU subsidy. In all years the cost of producing a tonne of bi cropped wheat was almost prohibitively high, consequently profits per hectare in bi-cropped treatments were very small compared to conventional treatments.

Table 1: Grain yield (t/ha @ 15% m)

Treatment	1995	1996	1997
Bi-cropped, no input	1.59	1.41	1.56
Bi-cropped, low input	3.11	2.4	2.57
Conventional, moderate input	8.63	8.19	6.0
Conventional, high input	10.09	9.76	7.34

Table 2: Whole crop silage yields (t/ha)

Treatment	1995	1996	1997
Bi-cropped, no input	9.28	7.61	8.86
Bi-cropped. low input	13.0	11.33	10.3
Conventional, moderate input	20.7	15.67	12.9
Conventional, high input	21.95	17.95	15.12

Table 3: Cost analysis 1994/95

Treatment	Cost/tonne (£)	Profit/ha (£)
Bi-cropped, low input	92.4	47.8
Bi-cropped, high input	70.9	131.8
Conventional , low input	42.7	586.5
Conventional, high input	47.4	628.0

Table 4: Cost analysis 1995/96

Treatment	Cost/tonne (£)	Profit/ha (£)
Bi-cropped, low input	88.7	52.54
Bi-cropped, high input	97.2	45.56
Conventional, low input	40.3	578.8
Conventional, high input	48.9	594.2

Table 5: Cost analysis 1996/97

Treatment	Cost/ tonne (£)	Profit/ha (£)
Bi-cropped, low input	112.5	-17.89
Bi-cropped, high input	106.27	-32.9
Conventional, low input	63.83	167.8
Conventional, high input	69.93	149.3

The investigations have demonstrated that it is possible to establish a winter wheat crop in a clover understorey provided that the crop is sown early in good sowing conditions. Additionally, it has been shown that the persistence of the clover understorey should not be a problem in such a system. However, grass weeds such as annual meadow grass rough stalked meadow grass, creeping bent and common bent did become problematical despite application of the herbicide triallate in October 1996. Spraying paraquat after the clover foliage had been removed did much to reduce the grass weed problem. However, this operation facilitated the establishment of chickweed and cleavers. Competition from weed species still represents a serious threat and further work is required on this aspect before the system is presented as a viable alternative to conventional arable systems.

Whole crop and grain yields have thus far been strongly related to external input levels irrespective of the agronomic system (i.e. conventional or bi-cropped). This is disappointing as it was expected that grain yields in the bi-cropped system would increase with successive crops as more biologically fixed N became available, previous experience had shown this to be the case (Jones and Clements, 1993). As long as low yields are obtained from bi-cropped treatments the cost of producing a tonne of bi-cropped wheat will be too high despite the low input costs of the bi-cropped treatments.

Yields from bi-cropped treatments were poor because of low numbers of ears/m^2 and grains/ear. The magnitudes of these two components are determined during the early stages of crop development. Lack of nitrogen during this critical phase prevented the formation of tillers and grain sites and so greatly reduced the yield potential of the bi-cropped treatments. This is evidenced by the fact that a small amount of nitrogen (50 kg/ha) supplied to one of the bi-cropped treatments during this period increased the number of ear/m^2 and the number of grains/ear. In addition seeding densities in the bi-cropped treatments may have imposed a further limitation to ear formation. Although bi-cropped treatments were sown at the same seeding rates as conventional treatments, large inter-row widths led to very high seeding densities in bi-cropped rows. Intense competition for nutrients at this sowing density may have limited the ability of plants to form ears.

Although the absolute yields of the bi-cropped treatments did not increase during the three years of the study, the relative yields of these treatments, yields expressed as a proportion of the yield of conventional treatments, did increase. There are a number of possible explanations. Increased take-all disease is likely to have reduced yields of wheat in the tilled area. Wheat yields should eventually increase in the bi-cropped area due to the supply of legume fixed nitrogen based on the fertility of clover containing pasture swards (Cowling, 1982; Clement and Williams, 1967).

Although grain yields were disappointing beneficial effects of the bi-cropping system were evident. Slug damage to cereals was lower in bi-cropped areas and earthworms were more prevalent in bi-cropped areas. Higher earthworm numbers are a typical feature of direct drilling cultivation (Schwerdtle, 1969). In the 1995/96 growing season some evidence was obtained of biological control of aphids in bi-cropped treatments. In June, aphids were found on leaves of the conventional treatments but not on the leaves of the bi-cropped treatments. Particularly interesting is a comparison of the three treatments which received no aphicide. In May and June the low input conventional treatment had significantly more leaf infesting aphids compared to both bi-cropped treatments.

Poor establishment was found to be a problem in the case of late sown winter cereals which yielded very poorly in comparison to early sown treatments. Bird damage was certainly a contributory factor although poor soil conditions and water logging did not help. Evidence of this problem was obtained in the Autumn of 1996. Unsettled weather and poor soil conditions from early October delayed sowing until very late in November. Although the bi-cropped wheat was sown in good conditions crop failure made re-sowing necessary. In contrast, wheat in the conventional area established without a problem. It appears that early sowing in good conditions is an essential pre-requisite in a bi-cropped production system.

In summary, the study has proved to be an interesting preliminary investigation of this bi-cropping system. Valuable information has been learned about the difficulties associated with such a system as well as the potential benefits that can be expected. Further research is needed, however, before such a system can be presented to the agricultural community. This research can be justified on the basis of the increasing consumer preference for agricultural products produced by environmentally benign farming practises.

CONCLUSIONS

- Winter wheat can be successfully established in an understorey of white clover if sown early in good conditions. However, competition from grass weed species represents a serious threat to the system.

- Whole crop and grain yields were strongly related to external input levels. Legume fixed nitrogen did not stimulate yield to any great extent.

- Beneficial effects of the bi-cropping system were evident. Slug damage was lower and earthworms were more prevalent in bi-cropped areas.

- Poor establishment and competition from clover led to poor yields when spring cereals were drilled into a white clover understorey.

- Poor establishment was also found to be a problem in the case of late sown winter cereals. Early sowing in good conditions is an essential pre-requisite of the system.

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